

2/PRTS

PCT/DE03/04121
2002P18915WOUS

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Description

Method and device for influencing combustion processes of fuels

The invention relates to a method for influencing combustion processes of fuels, in which electric means are used for guiding and/or changing a flame on a burner, according to the preamble of patent claim 1. In addition, the invention also relates to a device for carrying out the method by using stabilizing and/or pollutant-reducing means for influencing the flame during the combustion process, the means having field-producing electrodes on the burner.

The advantageous influences which electric fields can have on combustion flames have in principle been known for a long time. According to the publications

- *Industrial and Engineering Chemistry* 43 (1951), pages 2726 to 2731,
 - *12th Annual energy-sources technology conf.* (1989), pages 25 to 31 and
 - *AIAA Journal* 23 (1985), pages 1452 to 1454
- the actions of the electric field consist in improving the stability of the flame. According to
- *Combust. Flame* 78 (1989), pages 357 to 364 and
 - *Combust. Flame* 119 (1999), pages 356 to 366, a reduction in the soot emission is provided and, according to
 - *Fossil Fuel Combustion*, ASME 1991, pages 71 to 75 and
 - *Fluid Dynamics* 30 (1995), pages 166 to 174

a reduction in the emission of gaseous pollutants is provided. From *Combust. Flame* 55 (1984), pages 53 to 58, it is also known to influence combustion processes by means of electrical discharges, in particular corona discharges. Here too,

the result is intended to be an improvement in the flame stability and a reduction in the pollutant emission. One technical application of the aforementioned effects is described in WO 96/01394 A1. The common factor in all the methods described above is that the electrodes which are needed in order to produce the electric field or a discharge in the flame are in direct contact with the flame, specifically with the effect that charge carriers from the flame can reach the electrodes without hindrance.

The influence of electric fields on flames is based on the fact that the charge carriers present in the flame or produced therein by a discharge have forces exerted on them which displace the charge carriers. This is equivalent to the flow of an electric current. To turn the argument on its head, influencing a flame by means of an electric field or an electric discharge is not possible if no current can flow.

Investigations by the applicant have shown that, in order to influence flames of engineering dimensions, i.e. necessary with heating outputs in the range above 1 kW, electric field strengths are needed which, because of the gas discharges induced in the flame, require electric outputs which make the application of the method uneconomic or technically impossible. In the extreme case, an arc is formed within the flame. This applies primarily to DC electric fields. However, even in the application corresponding to the prior art of alternating electric fields or pulsed electric fields, the formation of impermissible high-current discharges can occur.

US 3 416 870 A explains that a flame can be influenced by electric means without impermissibly high currents, leading to a technically or economically unacceptable power consumption occurring in the flame to be influenced: for this purpose the flame and

at least one of the electrodes needed to produce the field are separated from each other by an insulating material in such a way that charge carriers from the flame cannot reach the electrodes insulated in this way. A time-variable voltage, that is to say in particular an alternating voltage or a pulsating direct voltage, is applied between the insulated electrode and a further electrode, which can be in contact with the flame. In the flame, it is possible for a current to flow until the capacitance of the capacitor formed by the electrodes and the insulating material is charged up or, expressed in other words, until the opposing electric field built up by the displacement current and the charge carrier accumulation effected by this prevents further charge carrier transport. After the charges accumulated on the surface of the insulating material during the current flow phase have been transported away by loss mechanisms, such as diffusion processes, a displacement current can flow again, and there is a renewed action of the electric field on the flame.

The same also results in principle from GB 1 013 015 A, in which electric and/or magnetic fields act on the flame to the same extent during the combustion process. Furthermore, EP 0 212 379 B1 discloses an arrangement for improving the combustion process in a combustion power station, in which there is an ionizing element for ionizing the gases involved in the combustion.

Experimental investigations on a device following the principle of US 3 416 870 A show that the effect of the electric field depends on the mark-space ratio of the pulsed voltage applied, in such a way that the effect that can be achieved is greater the longer a voltage is actually applied, that is to say the greater the mark-space ratio. Accordingly, the greatest effect would be achieved if a direct voltage were to be applied, if a current could also flow in this case. Since the flame is enclosed by an insulating material enclosure, the

application of a direct voltage without further special measures does not cause a current to flow and therefore remains without any effect in the intended sense.

Starting from this point, it is an object of the invention to specify an improved method and the associated device with which the combustion processes can be influenced positively in an economic manner.

According to the invention, the object is achieved by the measures of patent claim 1. An associated device is the subject of patent claim 7. Developments of the method and/or of the associated device are specified in the dependent claims.

In the invention, the flame and the electrodes are separated by an ion-conducting material, which means that the charge carrier transport is limited. In this case, the limitation of the charge carrier transport is advantageously carried out as a function of temperature, since the transition from the insulating state to the conductive state is temperature-dependent.

With the invention, the flame can be influenced without impermissibly high currents, leading to a technically or economically unacceptable power consumption, occurring in the flame to be influenced. During the action of the electric field on the flame, the charge carrier transport between flame and electrodes is limited and the occurrence of independent discharges, in particular arcs, is avoided. The result is a stabilizing and/or pollutant-reducing action.

The specified effects are all realized in a device according to the invention in that the flame and at least one of the electrodes needed to produce the field are separated from each other by an ion-conducting insulating material, which means that charge carriers from the flame cannot reach the

electrode insulated in this way. The ion-conducting material used is either aluminum oxide or, in particular, a zirconium oxide stabilized with additives. Such additives are in particular yttrium oxide.

Additional advantages of the invention result if the system is assigned sensors and control devices, which control the voltage applied to the electrodes in such a way that the combustion process is influenced in the desired manner. There are preferably sensors of which one measures the frequency of any combustion oscillations which may be present and another measures the pollutant concentration. Sensors supply the input signal to a control unit, which controls the frequency, amplitude and phase of the voltage applied to the electrodes in such a way that the combustion oscillations are minimized.

Further details and advantages of the invention emerge from the following figure description by using the drawing in conjunction with the patent claims. Figures 1 to 3 show three different exemplary embodiments of the invention, in each case in a schematic sectional illustration.

In the figures, identical or identically acting parts have the same designations. The figures will to some extent be described jointly in the following text.

According to figure 1, the flame 2 produced by a burner 1 for gaseous, liquid or prepared solid powdery fuels transported in gases or liquids is enclosed by an insulating material enclosure 3 in such a way that the fuel enters the enclosure at one end 4 and the waste combustion gas emerges on the other side 5. The insulating material enclosure 3 consists of an ion-conducting material as a specific, high-temperature resistant ceramic material, which, at temperatures of a few hundred Kelvin, such as are reached in the vicinity

of the gas flames in gas turbines, becomes electrically conductive as a result of ion conduction.

A material with properties of this type is in particular aluminum oxide or zirconium oxide stabilized with additives, which have ion-conducting properties. In particular, the second-named material is used in solid electrolyte ceramic high-temperature fuel cells, which are also known as SOFC (Solid Oxide Fuel Cell). There, this material permits the charge carrier transport - in this case via the ion-conducting electrolyte - at sufficiently high temperatures.

In figure 1, an electrode 6 is arranged inside the enclosure 3. The electrode 6 arranged inside the enclosure 3 can also be the housing 1 or another electrically conductive part of the burner 1, as illustrated in figure 2.

A further electrode 7 is arranged outside the enclosure 3. There can also be a plurality of electrodes at the same or different potential both inside and outside the enclosure 3, only one inner and one outer electrode being mentioned in the following text for the technical function, for reasons of simplicity.

In the exemplary embodiments of figures 1 and 3, the connections between the electrodes 7 and 9 and the power supply unit 8 are isolated electrically from the insulating material enclosure 3 which surrounds the burner chamber 5 by means of insulating leadthroughs 12 and 13.

The electrodes, illustrated as toroidal annular electrodes or else as cylindrical electrodes in the individual figures by way of example, can also be designed in another suitable shape. In particular, the electrodes can consist of films and be stuck to the insulating material enclosure. Furthermore,

the electrodes can be vapor-deposited or sprayed onto the insulating material enclosure by means of suitable methods.

In the figures, the electrodes 6, 7 and 1, 7 and, respectively, 9, 11 are connected via feed lines to the power supply unit 8, which supplies a direct voltage. One advantage of the invention is that the device specified also permits the application of an alternating voltage, a clocked direct voltage, a pulsed voltage or any desired combinations thereof.

The insulating material enclosure 3 can be designed such that it encloses the combustion chamber 5, as indicated in the exemplary embodiments of figures 1 and 2. However, it can also enclose an individual flame or else a plurality of flames within a combustion chamber. In a combustion chamber, a plurality of insulating material enclosures with the electrodes assigned to the latter can enclose one flame or in each case a plurality of flames.

In the exemplary embodiment of figure 3, the electrode 9 is shielded from the flame 2 by being enclosed completely and in a positive manner by an insulating material enclosure 10, while the electrode 11 can be in direct contact with the flame.

Instead of the gaseous fuel, solids can also be treated in the same way. In this case, it is important that smaller flames are formed above the solid fuel, which is normally located on a grate, are designated flamelets, as they are known, and are influenced in the sense described above.

The substantial advantage of the arrangements described by using the individual figures is that although the current through the flame is sufficient to effect pollutant-reducing and stabilizing effects, it always remains limited to such an extent that the build-up of a high-current, powerful discharge is ruled out.

To complete the examples illustrated in the figures, the system can be assigned sensors and control devices: A first sensor registers the frequency and/or amplitude of any combustion oscillations that may be present. A second sensor measures the pollutant concentration in the waste gas stream from the flame. The sensors supply input signals to a control unit, which controls or regulates the direct voltage applied to the electrodes and the frequency, amplitude and phase of any alternating or pulsed voltage which may be superimposed on the direct voltage, in such a way that the combustion oscillations and the pollutant concentration in the waste gas become a minimum.